Transport

Key quality factors at urban interchanges
Dell'Asin, Monzón and Lopez-Lambas

ice | proceedings

Proceedings of the Institution of Civil Engineers

http://dx.doi.org/10.1680/tran.13.00039
Paper 1300039
Received 01/06/2013 Accepted 03/03/2014
Keywords: rail & bus stations/statistical analysis/transport planning

ice
Institution of Civil Engineers
publishing

Key quality factors at urban interchanges

1 **Giulia Dell'Asin** MSc
PhD Candidate, Traffic Planning, SBB CFF FFS, Lucerne, Switzerland

2 **Andrés Monzón** PhD
Professor, Civil Engineering Transport Department, Universidad Politécnica de Madrid, Madrid, Spain

3 **María Eugenia Lopez-Lambas** PhD
Associate Professor, Civil Engineering Transport Department, Universidad Politécnica de Madrid, Madrid, Spain



Quality of service should not be overlooked in public transport planning and policy making, as it influences modal shift from car use to more sustainable means. Little research has been conducted on the quality of public transport interchanges from the perspective of current travellers (i.e. perceived quality). This work thus aimed to identify key quality factors at urban interchanges through an exploratory approach (multiple correspondence analysis) that provides novel elements for further investigation. The methodology was applied at interchanges in Madrid and Gothenburg and the data used in the analysis were collected through customer satisfaction surveys conducted in 2011. The analysis identified five key quality factors per interchange. Ticketing plays a key role at both interchanges while physical and environmental issues emerged at Avenida de América in Madrid, and services, temporal issues and interconnectivity characterise Gothenburg central station. Compared with other quality aspects, classical issues such as safety/security and information are not perceived as important by intermodal travellers.

1. Introduction

Over the last decade, major efforts have been made to increase modal shift from cars to public transport, leading to a reduction of the negative effects of the growth in car use, such as traffic congestion and air and noise pollution (EC, 2011). The current European strategy aims to improve this trend and ensure seamless door-to-door journeys other than by car (Hine and Scott, 2000).

The quality of public transport services strongly influences modal shifts to more sustainable means of transport and has an indirect influence on demand for public transport (Paulley *et al.*, 2006). Quality of service is thus highly relevant to public transport systems and therefore should not be overlooked in transport policies. This concept considers both managerial and customer perspectives (Parasuraman *et al.*, 1985) and is incorporated into European regulation on public transport service, which stresses the importance of focusing on passengers' expectations and perceptions (Aenor, 2003). Recent studies have identified quality attributes that characterise a public transport system according to passengers' perspective (Beirão and Sarsfield, 2007; De Oña *et al.*, 2012; Dell'Olio *et al.*, 2010).

According to Currie (2005), the transfer between one public transport vehicle and another is perceived as a great penalty. This includes all the time spent walking or waiting to complete a transfer, in addition to the effects of disruption. Public transport interchanges – the nodes of a transport system where passengers transfer between public transport means and between these and cars or other means of transportation (EC, 2009) – can help to reduce this penalty by facilitating transfers and minimising disruptions.

However, efficiency of intermodal points cannot be achieved if stakeholders neglect the issue of quality, from planning to management. Currently, the most critical issue is that the management of a single interchange zone may fall within the responsibility of several organisations (Lopez-Lambas and Monzón, 2010; Vassallo *et al.*, 2012). This is particularly difficult when short-distance trips are connected to long-distance trips and poor coordination among stakeholders prevents the possibility of seamless travel chains (Hermes, 2011).

Even though there are different infrastructure typologies that can be defined as 'transport interchanges' (bus/metro/rail stations, park & ride terminals, airports, etc.), there are common guidelines and good practices that have been developed for the design of transport interchanges (Blow, 2005; Mulroy, 2001). Quality at interchanges translates into a reliable supply and interconnectivity of services, adequate accessibility for all users, clear information, integrated ticketing systems, safety/security, services, functional use of available space and transfer distances, and attention to environmental and architectural issues (Bowers, 2011).

A review of the relevant literature indicates that researchers have mainly focused on the topic of quality linked to a single means of transportation (trips). Relatively little research has been conducted on the quality of service at interchanges as perceived by passengers (Dell'Asin, 2011).

The objective of this paper is to identify key quality factors (KQFs) at urban interchanges, according to the needs and perceptions of intermodal travellers. The proposed methodology is based on customer satisfaction surveys carried out at two European urban interchanges where both short- and long-distance trips are interconnected – Avenida de América interchange in Madrid and Gothenburg central station. The methodological approach is presented in Section 2 and Section 3 describes the case studies. Section 4 presents the surveys conducted at the interchanges and the main findings on key quality factors (KQFs) are reported in Section 5. Finally, conclusions are summarised in Section 6.

2. Methodology

A brief overview of approaches used to assess travellers' perceptions of public transport service is presented in this section, followed by a description of the methodology in this study.

2.1 Quantitative methods to assess perceived quality

Mathematical (statistical) approaches have been developed to better understand the data collected through passenger satisfaction surveys and to assess travellers' perceptions of public transport services. A review of the available literature reveals that researchers commonly implement regression analyses to identify quality determinants. Logit regression is generally preferred to multiple regression modelling because the quality attributes are usually treated as ordinal-scale variables with five or ten categories (Dell'Asin, 2011).

Morfoulaki *et al.* (2007) implemented multinomial logistic regression to estimate the probability of very satisfied customers, showing that customer satisfaction can be improved by focusing on specific issues (waiting times, frequency, etc.). Eboli and Mazzulla (2008) used the same approach to evaluate the importance of service quality attributes to global customer satisfaction and calibrated the models through stated preference data. Ordinal (ordered logit and probit) models have also been applied, using data from revealed preference surveys to identify which variables had the most influence on the overall perception of service quality (Rojo *et al.*, 2011). Other studies have used structural equation modelling (Eboli and Mazzulla, 2007) or the critical incident approach, which analyses the influence of negative critical incidents (i.e. cases that are particularly satisfying or dissatisfying) on customers' overall satisfaction (Friman, 2004).

2.2 Multiple correspondence analysis

The present study applied multiple correspondence analysis (MCA) to data obtained through customer satisfaction surveys that were designed to gain an understanding of the level of satisfaction of customers with a series of quality attributes at interchanges.

The implementation of MCA allows the exploration of latent constructs with regard to satisfaction of quality attributes, thus identifying so-called key quality factors. MCA is an exploratory multi-variate statistical technique for categorical data. It attempts to reduce the variability in a model by calculating the minimum number of factors that can explain the most variability (inertia) in the model (Hair *et al.*, 2010). MCA works in a similar way to principal components analysis (PCA), the most common statistical technique to extract from a set of variables a reduced set of factors that accounts for most of the variance in the variables. However, PCA extracts the variables that explain the largest amount of variance in the dataset, whereas MCA also shows the 'correspondence', or association, among the categories of variables.

This association is graphically represented through perceptual plots, whose interpretation is not always intuitive, since MCA uses the chi-squared distance rather than Euclidean distance between the points. In practice, perceptual plots represent the association of the categories according to the dimensions (factors) extracted in the analysis. The categories of the variables that most influence the calculation of the axes, representing the dimensions, are those that have the higher contribution and are at the extreme position.

This multi-variate statistical method was chosen for this study for two main reasons (Greenacre, 2007) – it assumes that the data are discrete variables and, being a non-parametric statistical method, it needs no special statistical assumptions.

MCA was performed on the quality attributes of customer satisfaction surveys (Section 4) carried out in two European case studies (Section 3). The data were analysed independently for each case study using Statistical Package for the Social Sciences (SPSS) Statistics, v.19.0. It was decided to retain the dimensions that accounted for approximately 80% of the variance.

3. Case studies

The methodology was applied to two case studies. These case studies are good examples of passenger intermodality and represent different typologies of an urban interchange – Avenida de América in Madrid as an urban interchange mainly related to the metro service and Gothenburg central as a railway station. They both embrace interconnections among short- and long-distance trips to/from the terminal and both public and private transport means.

3.1 Avenida de América interchange

Avenida de América interchange (Figure 1) is located in the north east of Madrid, Spain. Some 152 000 passengers transfer daily

Figure 1. Avenida de América interchange

Figure 2. Gothenburg central station

through the interchange, which is part of the Madrid regional plan for public transport interchanges (CRTM, 2010) for achieving the goal of seamless mobility between long and regional journeys. The interchange came into service in 2000. Comprising four underground floors, it offers metro services as well as national, regional and urban bus services. In 2012 it was revamped to improve air conditioning, safety/security facilities, platform screens and transfer walkways.

3.2 Gothenburg central station

Gothenburg central station (Figure 2) is the major national passenger transport hub in the south west of Sweden. It is located in the central area of Gothenburg, with plans to develop into an attractive communications hub and regional centre (City of Gothenburg, 2012). About 101 000 passengers go through the station every day to use tram, urban and international rail and bus services. The complex consists of three buildings – the old restored railway station (1856–1857), the new meeting place (2003) and the relatively new bus terminal (1996). Together, they constitute a travel centre with shops, cafes, restaurants, offices and a hotel.

4. Data

Customer satisfaction surveys were carried out as part of the Hermes (High Efficient and Reliable arrangeMEnts for croSs-modal transport) project of the EU 7th Framework Programme (Hermes, 2011). The questionnaire used consisted of different modules and respondents were asked to answer questions on socio-demographic profile and travel patterns (age, gender, purpose, means of transportation, waiting time, familiarity with the interchange, etc.) and to rate their satisfaction of 26 quality attributes, grouped into five categories (Table 1), on a Likert scale ranging from positive (5) to negative (1) values.

The surveys were based on random sampling, with every element of the population having a known and equal probability of selection. The sample size, calculated according to the Bartlett *et al.* (2001) formulation for a finite population, was 383 travellers per case study to achieve a 95% interval of confidence. In the end, the effective sample size was 379 in Madrid and 508 in Gothenburg, leading to a lower margin of error for the Swedish case study (±4·0%). The surveys, carried out in April and May 2011 at rush hour on working days, addressed travellers over the age of 15 who passed through the urban interchanges (at bus stops, railway platforms, terminal halls, etc.).

According to the questionnaires collected, travellers at Avenida de América are mainly female (56%) with the majority of respondents aged 21 to 35 (51%). They mainly reach the interchange by metro (66%) and leave it by long-distance bus

Category	Label	Description
Supply	Su1	Coordination of timetables between different transport means
	Su2	Possible travel connections between origin and destination
	Su3	Possibility of combining different transport means
Time	Ti1	Punctuality of transport operators
	Ti2	Total time for check-in services (at a counter with personnel)
	Ti3	Total time spent for baggage drop
	Ti4	Total waiting time
Space	Sp1	Space at the station (not overcrowded)
	Sp2	Total seating capacity
	Sp3	Access to luggage storage
Information	In1	Information signs
	In2	Availability of staffed information counters
	In3	Possibility of buying different types of tickets (ticketing machines)
	In4	Possibility of buying different types of tickets (at a counter with personnel)
	In5	Personnel's service at ticket counters
	In6	Possibility of rescheduling tickets
Services	Se1	Shopping facilities
	Se2	Additional services (banking, postal services)
	Se3	Access to toilets
	Se4	Cleanliness
	Se5	Access to internet
	Se6	Access to lounges/waiting rooms
	Se7	Ventilation
	Se8	Safety/security
	Se9	Baby care facilities, play areas
	Se10	Access to parking spaces (car, bicycles)

Table 1. Quality attribute variables used in Hermes customer satisfaction surveys

(92%). The most common purpose of the intermodal journey is private issues (visiting family/friends) (64% of respondents); study was the least common purpose (4%). The travellers interviewed generally spend a significant amount of time in Avenida de América (58% spend more than 45 min) and are quite or very familiar with it (68%).

In Gothenburg central station, travellers are mainly young women (65%), with the most common age groups being 15–20 years and 21–35 years (together accounting for 60% of respondents). The travellers interviewed mainly reach the terminal by long-distance train (37%) or tram/urban bus (together accounting for 38%) and mainly leave it by long-distance train (73%). Private purposes (shopping) are the most common reason for travelling (58%), followed by business (23%). Time spent in the terminal is generally high, with 42% of interviewed travellers spending more than 45 min there. Familiarity with the terminal is also good, with 76% of the sample being quite or very familiar with it.

5. Results

This section presents the main findings from implementation of MCA to the two case studies. KQFs were labelled to better understand the outputs and the underlying constructs of quality. Interpretation of the factors was possible by looking at the measures of discrimination generated by SPSS, representing the degree of association between each quality attribute and each dimension. Only symmetrical perceptual plots of the first two dimensions, which together account for the largest amount of inertia, are reported in this paper.

5.1 Avenida de América interchange

Multiple correspondence analysis was performed on 21 quality attributes, since five variables (Su1, Ti2, In1, Se6, Se10) could not be integrated in the analysis due to a large amount of missing data (the questionnaires could not be completed because travellers interrupted the interview or had to catch their next transport connection). Table 2 shows the five dimensions that were retained in the analysis of Avenida de América, accounting for 79% of the total variance explained by the model.

Looking at the measures of discrimination in Table 3, it can be observed that variables representing supply aspects are weakly associated with all the axes and are consequently perceived as less important by travellers.

Dimension	Cronbach's α	Variance accounted for		
		Total (singular value)	Inertia	Proportion of inertia: %
1	0·812	4·414	0·210	21·020
2	0·768	3·726	0·177	17·743
3	0·743	3·419	0·163	16·280
4	0·679	2·832	0·135	13·486
5	0·582	2·245	0·107	10·692
Total	—	20·840	0·992	—
Mean	0·697	2·977	0·142	14·177

Table 2. MCA output: Avenida de América, Madrid

Quality attribute	Dimension					Average
	1	2	3	4	5	
Su2	0·141	0·034	0·089	0·041	0·022	0·065
Su3	0·138	0·149	0·127	0·119	0·121	0·131
Ti1	0·197	0·062	0·181	0·084	0·092	0·123
Ti3	0·208	0·253	0·111	0·119	0·067	0·152
Ti4	0·197	0·084	0·229	0·045	0·050	0·121
Sp1	**0·324**	0·169	**0·373**	0·121	0·194	0·236
Sp2	**0·352**	0·118	0·213	0·083	0·204	0·202
Sp3	0·250	0·055	0·110	0·098	0·126	0·128
In2	0·093	0·033	0·167	0·192	0·102	0·117
In3	0·098	**0·500**	0·065	**0·332**	0·045	0·208
In4	0·191	0·067	0·120	**0·315**	0·015	0·142
In5	0·223	0·097	0·117	**0·394**	0·051	0·177
In6	0·094	**0·500**	0·071	**0·337**	0·035	0·208
Se1	0·188	0·146	0·170	0·035	0·097	0·127
Se2	0·178	0·203	0·130	0·152	0·060	0·144
Se3	0·201	0·046	**0·255**	0·067	0·073	0·120
Se4	0·298	0·098	0·208	0·016	**0·280**	0·180
Se5	0·196	**0·634**	0·154	0·133	0·129	0·249
Se7	**0·374**	0·047	**0·339**	0·109	**0·258**	0·225
Se8	0·228	0·089	0·182	0·018	0·065	0·116
Se9	0·244	0·340	0·008	0·021	0·158	0·154
Total	4·414	3·726	3·419	2·832	2·245	3·327
Variance: %	21·020	17·743	16·280	13·486	10·690	15·844

Table 3. Measures of discrimination: Avenida de América

Dimension 1, which accounts for the most variance in the model (21%), is mainly related to space at the station (Sp1), total seating capacity (Sp2) and ventilation (Se7) within the interchange. KQF1 was thus labelled 'physical', mainly representing aspects of the physical space and the environmental conditions.

The second dimension relates to the possibility of buying different types of tickets at ticketing machines (In3), the availability to reschedule tickets (In6) and access to internet (Se5). KQF2, mainly representing issues that involve the use of machines or PCs, laptops, smartphones and so on, was labelled 'technology',

Dimension 3, similarly to dimension 1, relates to physical and environmental aspects (Sp1, Se7), with a strong association to access to toilets (Se3). KQF3 is thus associated with issues that create a pleasant and healthy space to stay and was labelled 'comfort'.

The fourth dimension mainly relates to the possibility of buying different types of tickets either at ticketing machines (In3) or from staff at counters (In4), personnel service (In5) and the availability to reschedule tickets (In6). KQF4 was labelled 'ticketing'.

The fifth dimension is associated with cleanliness of the entire terminal (Se4) and ventilation (Se7). This is another factor associated with environmental and comfort issues: KQF5 was labelled 'wellbeing'.

Figure 3 illustrates the perceptual plot of dimensions 1 and 2, which together account for the large amount of inertia (39%), detecting structural relationships between the categories of the ordinal-scale variables (quality attributes). Regarding the axis of the first dimension, the lowest ratings of satisfaction fall into the negative side, while the highest ratings fall into the positive area. Therefore, KQF1 (physical) represents extreme satisfactions of quality: very low (1) or very high (5). As regards the axis of the second dimension, the projections of the point (the categories) are plotted near the origin, indicating that there is no clear distinction between the opposite poles of the axis. In this case, the interpretation of the axis is hazardous and for KQF2 (technology) it is not possible to identify a clear satisfaction pattern.

Regarding the other dimensions, only a summary is given here, indicating the different levels of satisfaction associated

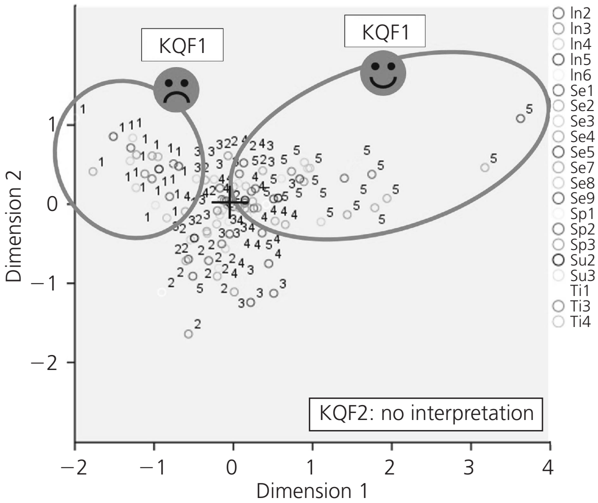

Figure 3. Avenida de América – perceptual plot KQF1–KQF2

with the axes (Table 4). Travellers at Avenida de América interchange either strongly dislike or are very enthusiastic about the factors and only KQF4 (ticketing) was skewed to low values.

	Significant quality attributes	Label	Level of satisfaction	
			Negative axis of perceptual plot	Positive axis of perceptual plot
KQF1	Sp1, Sp2, Se7	Physical	Very low	Very high
KQF2	In3, In6, Se5	Technology	Interpretation hazardous	
KQF3	Sp1, Se3, Se7	Comfort	High	Very low/very high
KQF4	In3, In4, In5, In6	Ticketing	Very low	Medium
KQF5	Se4, Se7	Wellbeing	Low	Very low/very high

Table 4. Summary of KQFs for Avenida de América

Dimension	Cronbach's α	Variance accounted for		
		Total (singular value)	Inertia	Proportion of inertia: %
1	0·892	6·982	0·279	21·902
2	0·829	4·893	0·196	19·611
3	0·793	4·181	0·167	16·780
4	0·671	2·810	0·112	11·222
5	0·639	2·590	0·104	10·453
Total	—	21·456	0·858	—
Mean	0·764	4·2912	0·171	15·993

Table 5. MCA output: Gothenburg central station

5.2 Gothenburg central station

For the Gothenburg case study, MCA was performed on 25 quality attributes – only one variable (In5) could not be considered due to missing data. Table 5 shows the five dimensions used in the analysis of Gothenburg central station, accounting for 80% of the total variance explained by the model.

Table 6 lists the measures of discrimination. It can be observed that variables related to physical aspects have low values, meaning they contribute less to forming the dimensions and are therefore perceived as less important by travellers.

Dimension 1, which explains the most variance in the model (22%), is mainly related to the total time spent waiting for baggage drop (Ti3), the total waiting time (Ti4), the availability of staffed information counters (In2) and additional services (Se2). KQF1 was thus labelled 'time', mainly representing temporal aspects and issues related to saving time (e.g. banking services or the availability of getting information directly from somebody).

The second dimension relates to several quality attributes representing service issues. It is mainly associated with additional

Quality attribute	Dimension					Average
	1	2	3	4	5	
Su1	0·267	0·170	0·158	**0·380**	0·205	0·236
Su2	0·317	0·137	0·134	**0·278**	0·194	0·212
Su3	0·311	0·237	0·186	**0·289**	0·224	0·250
Ti1	0·211	0·068	0·096	0·080	0·095	0·110
Ti2	0·226	0·049	0·147	0·083	0·155	0·132
Ti3	**0·322**	0·113	0·135	0·218	0·161	0·190
Ti4	**0·351**	0·216	0·110	**0·363**	0·088	0·226
Sp1	0·286	0·173	0·040	0·078	0·051	0·126
Sp2	0·277	0·198	0·110	0·031	0·015	0·126
Sp3	0·173	0·108	0·162	0·046	0·041	0·106
In1	0·306	0·068	0·145	0·065	0·079	0·133
In2	**0·324**	0·224	0·238	0·021	0·024	0·166
In3	0·320	0·237	**0·304**	0·035	0·033	0·186
In4	0·296	0·297	**0·319**	0·041	0·043	0·199
In6	0·255	0·219	0·261	0·094	0·059	0·178
Se1	0·270	0·147	0·112	0·025	0·027	0·116
Se2	**0·346**	**0·319**	0·157	0·068	0·021	0·182
Se3	0·300	**0·326**	0·156	0·062	0·065	0·182
Se4	0·312	0·249	0·098	0·044	0·100	0·161
Se5	0·300	**0·311**	0·252	0·102	**0·231**	0·239
Se6	0·320	0·270	0·177	0·072	0·107	0·189
Se7	0·249	0·222	0·108	0·088	0·058	0·145
Se8	0·262	0·222	0·156	0·027	0·042	0·142
Se9	0·196	0·172	0·239	0·117	**0·245**	0·194
Se10	0·187	0·142	0·182	0·103	**0·227**	0·168
Total	6·982	4·893	4·181	2·810	2·590	4·291
Variance: %	21·902	19·611	16·780	11·222	10·453	15·994

Table 6. Measures of discrimination for Gothenburg central station

services (Se2), access to toilets (Se3) and access to internet (Se5). KQF2 was labelled 'services'.

The third dimension is highly associated with the possibility of buying different types of tickets at ticketing machines (In3) and from staff at counters (In4). KQF3 was thus labelled 'ticketing'.

Dimension 4 mainly relates to the coordination of timetables (Su1), possible travel connections between origin and destination (Su2), the possibility of combining different transport means for the journey (Su3) and the total waiting time (Ti4). KQF4 is thus associated with issues that enhance connections between means and the supply at the interchange. It was labelled 'transfer connectivity'.

The fifth dimension is associated with internet access (Se5), the provision of baby care facilities/play areas (Se9) and access to parking spaces (Se10). KQF5 was labelled 'additional facilities' since it is associated with issues that are important but not strictly necessary, and could be considered as plus values for the interchange.

Looking at the perceptual plot of dimensions 1 and 2, the level of satisfaction of the KQFs can be investigated, which together account for 41% of the variance (Figure 4).

As regards the axis of the first dimension, the lowest satisfaction ratings fall into the positive side, while the highest ratings fall into the negative area. Therefore, KQF1 (time) represents extremes of satisfaction: very low (1) or very high (5). The poles of axis 2 distinguish between medium/high satisfaction (3 and 4 respectively) on the positive side and very low/very high satisfaction on the negative side. KQF2 (services) has different perceptions among travellers. Table 7 summarises the level of satisfaction associated with the axes of the other dimensions. Travellers in Gothenburg central station have extreme perceptions of the KQFs and only KQF4 (connectivity) is skewed to low values.

5.3 Comparison

The analyses show that in both cases there are five KQFs explaining (summarising) travellers' perceptions of quality attributes. MCA provides two types of information – which are the perceived quality attributes and how are they perceived (i.e. the level of satisfaction). It is worth noting that in both cases the level of satisfaction with the QFKs was quite different among travellers, ranging from very low to very high ratings. Only ticketing in Madrid and connectivity in Gothenburg were skewed to low values, since the axes distinguish between medium and very low ratings (Tables 4 and 7).

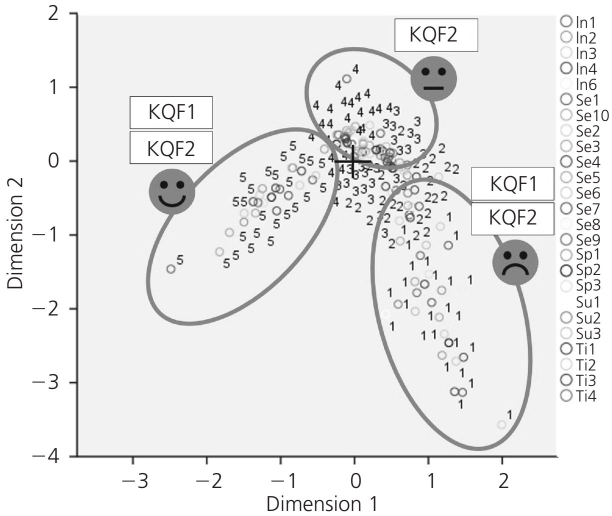

Figure 4. Gothenburg central station – perceptual plot KQF1–KQF2

	Significant quality attributes	Label	Level of satisfaction	
			Negative axis of perceptual plot	Positive axis of perceptual plot
KQF1	Ti3, Ti4, In2, Se2	Time	Very high	Very low
KQF2	Se2, Se3, Se5	Services	Very low/very high	Medium/high
KQF3	In3, In4	Ticketing	Very low/high	Medium
KQF4	Su1, Su2, Su3, Ti4	Transfer connectivity	Medium	Very low
KQF5	Se5, Se9, Se10	Additional facilities	Very high	Very low

Table 7. Summary of KQFs for Gothenburg central station

Ticketing plays a key role for both interchanges and the possibility of buying different types of tickets is crucial to passengers' perception of quality. However, differences were found from application of the methodology. Intermodal travellers in Madrid mainly perceived aspects related to the physical space, comfort and environmental conditions as important. On the contrary, in Gothenburg other aspects, such as temporal issues, the provision of services and interconnectivity among different means of transportation were perceived as important.

The differences can be explained in terms of the different contexts and traveller profiles. According to the survey in Madrid, regular travellers, travelling to visit friends, spend a considerable amount of time in the interchange. They thus need a comfortable and healthy place to wait for their next long-distance trip (by bus). According to the survey in Gothenburg, respondents are familiar with the interchange, spend a lot of time there and are travelling for shopping or business purposes. Their need is for a range of possibilities to link short and long trips. It is worth stressing that modal interconnectivity was perceived with different levels of satisfaction – low for shopping travellers and high for business travellers. This can be explained by the fact that shopping travellers are not regular users and tend to be more critical than regular business travellers, who are generally familiar with interconnectivity opportunities.

6. Conclusion

Travellers' perceptions of quality attributes were better understood through the KQFs identified through MCA in Madrid and Gothenburg. Ticketing plays a key role at both interchanges, being a necessary requirement of better interconnectivity in order to experience a seamless long-/short-distance journey (Bak, 2010; Rojo *et al.*, 2011). Physical and environmental issues emerged in Madrid, in accordance with other studies where the space, the aesthetic and health environment of interchanges were found to be determinants in the use of public transport (Cascetta *et al.*, 2013; Van Hagen, 2011). Services, temporal issues and interconnectivity emerged as important in Gothenburg, with contrasting perceptions because of different travellers' needs, confirming the complexity of timetable coordination and the importance of temporal aspects for interchanging commuters (Hutchinson, 2009; Stradling, 2002).

It is surprising that 'classical' issues such as safety/security and information did not emerge from the analysis in this study. This could be because safety/security are indirectly considered (integrated) in spatial and environmental issues (not isolated spaces, well-lit waiting rooms, etc.). Regarding information (understood as signage), this could be because efficient improvements have been introduced at the interchanges over the past few years, perhaps driven by the fact that information is often considered the main determinant for public transport quality (Grotenhuis *et al.*, 2007).

This study holds some limitations since the customer satisfaction surveys were based on a simple random sampling plan and were conducted on weekdays – the perception of quality of transport interchanges at weekends may also influence the results. For example, the needs of commuters (or business users) and holiday travellers are different and this issue could not be considered in the analysis. Furthermore, the risk in these kinds of surveys, which are carried out on site through questionnaires, is to lose some information on positive aspects because respondents generally tend to focus on those factors that are wrong and need, in their view, changing. It is also worth pointing out that MCA is a descriptive/exploratory technique and thus the results are not useful by themselves for decision making or for making predictions, although they can provide a deep insight into the topic 'quality of service'.

The main outcome of the methodology used in this study was the identification of KQFs at urban interchanges. This can be considered as a starting point for further analyses and the development of policy macro-strategies. The approach is exploratory and additional research to clustering intermodal travellers should integrate the assessment of perceived quality at urban interchanges.

Acknowledgements

This study was possible thanks to data collected in the Hermes (High Efficient and Reliable arrangeMEnts for croSsmodal transport) project of the EU 7th Framework Programme under contract no. TCP8-GA-2009-234082. Thanks also go to Andrea Alonso, researcher at TRANSyT-UPM, for providing a coherent compilation of data.

REFERENCES

Aenor (2003) UNE-EN 13816: Transportation. Logistics and services. Public passenger transport. Service quality definition, targeting and measurement. Aenor, Madrid, Spain.

Bak M (2010) Integrated ticketing in passenger transport as a choice to improve interconnectivity. *Proceedings of 12th World Conference on Transport Research, Lisbon, Portugal*.

Bartlett JE, Kotrlik JW and Higgins C (2001) Organizational research: determining appropriate sample size for survey research. *Information Technology, Learning, and Performance Journal* **19(1)**: 43–50.

Beirão G and Sarsfield JA (2007) Understanding attitudes towards public transport and private car: a qualitative study. *Transport Policy* **14(6)**: 478–489.

Blow C (2005) *Transport Terminals and Modal Interchanges – Planning and Design*. Architectural Press, Oxford, UK.

Bowers S (2011) All change? Motorway interchanges for public transport. *Proceedings of the Institution of Civil Engineers – Transport* **164(4)**: 209–220.

Cascetta E, Carteni A and Carbone A (2013) La progettazione quality-based nel trasporto pubblico locale. Il sistema di metropolitana regionale della Campania. *Ingegneria Ferroviaria* **3(2013)**: 241–261 (in Italian).

City of Gothenburg (2012) *RiverCity Gothenburg. Vision*. City of Gothenburg, Gothenburg, Sweden.

CRTM (Consorcio Regional de Transportes de Madrid) (2010) *Plan de Intercambiadores – Madrid*. CRTM, Madrid, Spain.

Currie G (2005) The demand performance of bus rapid transit. *Journal of Public Transportation* **8(1)**: 41–55.

Dell'Asin G (2011) *Methodology for the Assessment of Quality in Public Transport Interchanges*. INECO, Madrid, Spain, Cuadernos de investigación del transporte 11-3.

Dell'Olio L, Ibeas A and Cecín P (2010) Modelling user perception of bus transit quality. *Transport Policy* **17(6)**: 388–397.

De Oña J, De Oña R and Calvo F (2012) A classification tree approach to identify key factors of transit service quality. *Expert Systems with Applications* **39(12)**: 11164–11171.

Eboli L and Mazzulla G (2007) Service quality attributes affecting customer satisfaction for bus transit. *Journal of Public Transportation* **10(3)**: 21–34.

Eboli L and Mazzulla G (2008) A stated preference experiment for measuring service quality in public transport. *Transportation Planning and Technology* **31(5)**: 509–523.

EC (European Commission) (2009) *Efficiency in Sustainable Mobility – Thematic Research Summary*. EC, Brussels, Belgium.

EC (European Commission) (2011) *White Paper. Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System*. EC, Brussels, Belgium, COM(2011) 144 final.

Friman M (2004) Implementing quality improvements in public transport. *Journal of Public Transportation* **7(4)**: 49–65.

Greenacre M (2007) *Correspondence Analysis in Practice*, 2nd edn. Chapman & Hall/CRC, Boca Raton, FL, USA.

Grotenhuis J, Wiegmans B and Rietveld P (2007) The desired quality of integrated multimodal travel information in public transport: customer needs for time and effort savings. *Transport Policy* **14(1)**: 27–38.

Hair JF, Anderson RE, Tatham RL and Black WC (2010) *Multivariate Data Analysis*, 7th edn. Pearson Prentice-Hall, Upper Saddle River, NJ, USA.

Hermes (2011) *Hermes Project. Deliverable 5 – Case Studies*. Transport Programme of the 7th RTD Framework Programme, Brussels, Belgium.

Hine J and Scott J (2000) Seamless, accessible travel: users' views of the public transport journey and interchange. *Transport Policy* **7(3)**: 217–226.

Hutchinson TP (2009) The customer experience when using public transport: a review. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **162(3)**: 149–157.

Lopez-Lambas ME and Monzón A (2010) Private funding and management for public interchanges in Madrid. *Research in Transportation Economics* **29(1)**: 323–328.

Morfoulaki M, Tyrinopoulos Y and Aifadopoulou G (2007) Estimation of satisfied customers in public transport systems: a new methodological approach. *Journal of the Transportation Research Forum* **46(1)**: 63–72.

Mulroy TM (2001) How do we make transport interchanges work? *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **145(1)**: 55–59.

Parasuraman A, Zeitlham VA and Berry LL (1985) A conceptual model of service quality and its implications for future research. *Journal of Marketing* **49(4)**: 41–50.

Paulley N, Balcombe R, Mackett R *et al.* (2006) The demand for public transport: the effects of fares, quality of service, income and car ownership. *Transport Policy* **13(4)**: 295–306.

Rojo M, Gonzalo-Orden H, Dell'Olio L and Ibeas A (2011) Modelling gender perception of quality in interurban bus services. *Proceedings of the Institution of Civil Engineers – Transport* **164(1)**: 43–53.

Stradling SG (2002) Transport user needs and marketing public transport. *Proceedings of the Institution of Civil Engineers – Municipal Engineer* **151(1)**: 23–28.

Van Hagen M (2011) Effects of station improvement measures on customer satisfaction. *Proceedings of the European Transport Conference, Glasgow, UK*.

Vassallo JM, Di Ciommo F and García A (2012) Intermodal exchange stations in the city of Madrid. *Transportation* **39(5)**: 975–995.